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THE PROPERTIES OF HIGHLY LUMINOUS IRAS GALAXIES

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ABSTRACT

From a complete sample of 154 galaxies identified with IRAS sources in a 304 deg² area centered on the South Galactic Pole, a sub-sample of 58 galaxies with $L_{IR}/L_B > 3$ has been chosen. Low resolution spectra have been obtained for 30% of the sub-sample and redshifts and relative emission-line intensities have been derived. As a class these galaxies are very luminous with $<L_{IR}> = 2.9 \times 10^{11}\ L_\odot$ and (L_{IR}) max $= 1.3 \times 10^{12}\ L_\odot$. CCD images and JHK photometry have been obtained for many of the sub-sample. The galaxies are for the most part newly identified and are optically faint ($16 < B < 21$), with a majority showing evidence of a recent interaction. Radio continuum observations of all galaxies of the sub-sample have recently been obtained at 20 cm (VLA) with about 75% being detected in a typical integration time of about 10 minutes.

I INTRODUCTION

We are engaged in a systematic, large-scale program of optical identification of IRAS sources (see Savage et al., 1986, and Wolstencroft et al, 1986), one of whose principal motivations is to establish a large and complete infrared selected sample of galaxies detected by IRAS (so-called IRAS galaxies). With such a sample we can carry out unbiassed studies designed to elucidate the origin of the high infrared luminosity ($L_{IR} \gtrsim 10^{11} L_\odot$) found in many of these galaxies. We have recently begun a study of such a sample that comprises 154 IRAS galaxies identified in a 304 deg² area centred on the South Galactic Pole (Wolstencroft et al., 1986), and this paper describes current progress.

In the first stage of this study we have selected a sub-sample of galaxies likely to contain a high proportion of the most infrared luminous galaxies in the complete sample. For an infrared selected sample, L_{IR}/L_B is correlated with L_{IR} but not with L_B (Soifer et al., 1986), which implies that much of the variation seen in L_{IR}/L_B in such a sample (0.2 to 200 in our case) is due to changes in L_{IR}. Our sub-sample comprises 58 galaxies with $L_{IR}/L_B > 3$: the L_{IR}/L_B histogram is shown in figure 1. In this paper we give some preliminary results of follow-up studies in progress, which include low dispersion spectroscopy, CCD imaging, near infrared photometry and radio continuum mapping.

II FOLLOW-UP STUDIES

Redshifts have been obtained so far for 30% of the sub-sample, using either the grism/CCD combination on the 2.2m University of Hawaii telescope (5000 to 6900Å, 4Å resolution) in long slit mode, or the low dispersion spectrograph and reticon detector on the 1.9m SAAO telescope (3500 to 7500Å, 6Å resolution). For this limited sample the infrared luminosity falls in the range 3.8 x 10^{10} $L_\odot$ to 1.1 x 10^{12} $L_\odot$ with $<L_{IR}>$ = 2.9 x 10^{11} $L_\odot$: the L_{IR} histogram is shown in fig 2. The properties of a few selected galaxies are given in Table 1.

Table 1

Properties of Selected Galaxies

IRAS Name	z	$L_{IR}/L_\odot$	L_{IR}/L_B	B	K	J-K	H-K	B-K
00308-2238	0.0378	2.0 x 10^{11}	25	17.0	12.71	1.43	0.51	4.3
00335-2732	0.0670	1.1 x 10^{12}	46	17.2	14.16	0.65	0.08	3.0
00402-2350	0.0229	3.3 x 10^{11}	13	14.5	10.22	1.29	0.37	4.3
01050-3305	0.0347	2.5 x 10^{11}	35	17.0	11.72	1.32	0.42	5.3

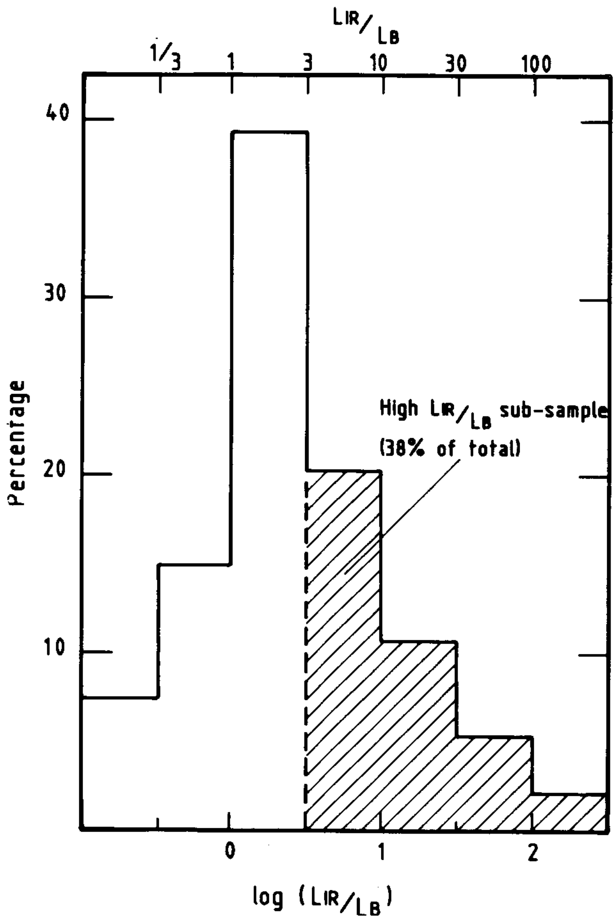

Figure 1. Histogram of L_{IR}/L_B for the complete sample of 154 IRAS galaxies in the SGP field, and for the sub-sample (L_{IR}/L_B > 3).

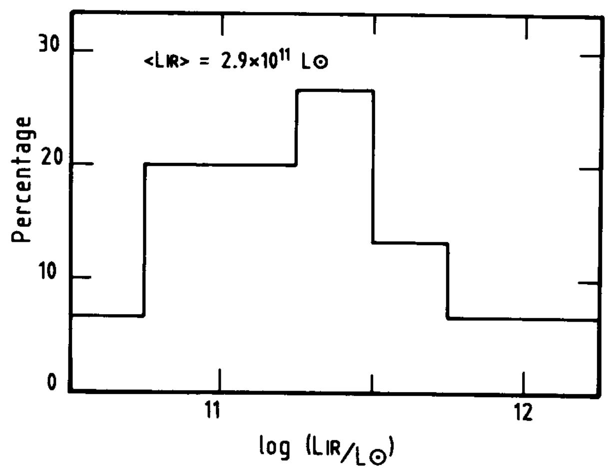

Figure 2. Histogram of L_{IR} for the sub-sample.

From visual inspection of the images on the UKST plates (see Plate 1 of Wolstencroft et al., 1986) it is clear that at least half of the galaxies in the sub-sample are 'interacting', based either on the presence of bridges, tails, double nuclei or other signs of disturbance, or on the presence of a galaxy of comparable brightness that is very close on the sky.

Broad based CCD images and low resolution spectra have been obtained, for about 30% of the sample, and these will allow a more quantitative test of this suspicion. A particularly interesting source is IRAS 00335 - 2732, which is identified with the most luminous galaxy in the sub-sample with $L_{IR} = 1.1 \times 10^{12}\ L_{\odot}$. There are two galaxies 6 arc sec apart at the position of the IRAS source, with diffuse emission extending between the two galaxies and also north of the fainter galaxy (see fig 3). The redshift of the brighter (B = 17.2) of the two galaxies is z = 0.0670, corresponding to a separation of 8Kpc between the galaxies (H_0 = 75 km sec^{-1} Mpc^{-1}) if they are truly interacting. The correlation between log (L_{IR}/L_B) and log (F_{100}/F_{60}) for the complete sample (Wolstencroft et al., 1986) may be interpreted (de Jong et al., 1984), in its simplest terms, as a combination of two components : (1) contributions by warm dust (T~60K) heated by young stars, and (2) cooler dust heated by the general interstellar radiation field (i.e. cirrus). In the case of IRAS 00335 - 2732, which has the most extreme temperature of the sample (F_{60}/F_{100} = 1.44), the warm dust completely dominates the far infrared emission.

Figure 3. CCD image of IRAS 00335-2732 taken in the R band and with the Galileo CCD camera at the Cassegrain focus of the 2.2m University of Hawaii telescope. North is up and East is to the right. The faint galaxy 6 arc sec due east appears to be interacting with the brighter compact galaxy.

Near infrared colours (J-K, H-K) of a few of these galaxies have been measured on UKIRT with a 20 arc sec aperture. Some typical results are shown in fig 4. For comparison we show the range of colours found by Wolstencroft and Davies (in preparation) for an optically selected sample of normal Sbc galaxies (defined by the dashed rectangle). There is a wide spread in colours, with the extreme cases ranging from the most luminous galaxy IRAS 00335 - 2732 (J-K = 0.65, H-K = 0.08), which has very blue colours, to two galaxies with unusually red H-K colours, IRAS 01358-3300 and 01199-2307. Although all three galaxies show very clear signs of interaction, so also do the sources contained in or close to the normal galaxy sequence (galaxies in the latter sequence have colours that may perhaps be explained primarily as a mixing of bulge and point nucleus colours). If interactions have any significant influence on these near infrared colours it is most likely to occur near the peak of a burst of star formation when the maximum blueing takes place. Clearer discrimination between galaxy types using near infrared colours should be possible for those galaxies bright enough for L' measurements to be made.

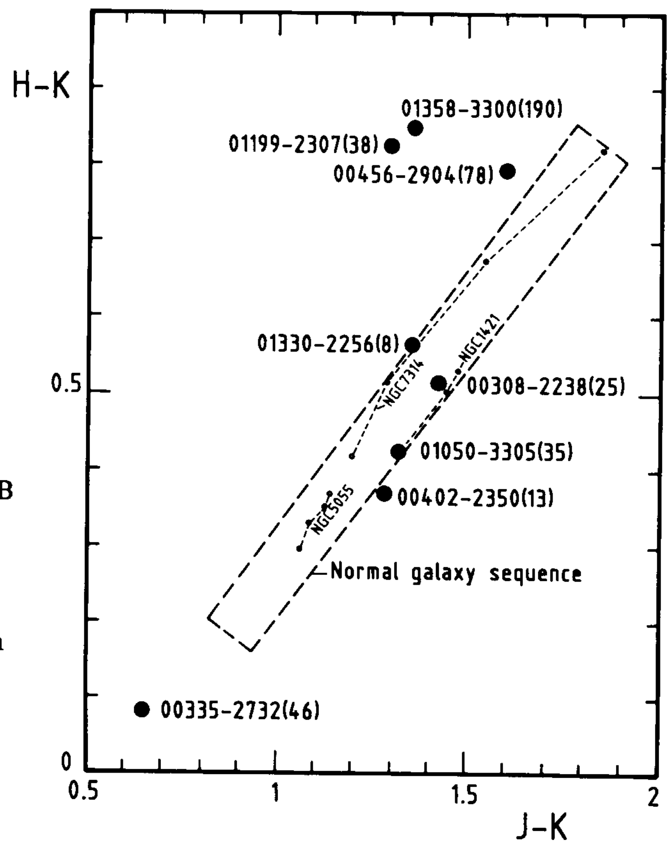

Figure 4. Near infrared colours (H-K, J-K) measured in a 20 arc sec aperture of selected galaxies with $L_{IR}/L_B > 3$. The values of L_{IR}/L_B are shown in brackets after the IRAS name. For comparison the range of colours are shown (dashed rectangle) for an optically selected sample of normal Sbc galaxies (with $0.1 < L_{IR}/L_B < 1.6$) measured with concentric apertures between 5 and 20 arc sec (Wolstencroft and Davies, in preparation). The aperture dependence for three normal galaxies are indicated.

Radio continuum mapping of all galaxies of the sub-sample has been completed recently but analysis is still at a very preliminary stage. With exposures typically of 10 minutes with the A/B array of the VLA (3 arc sec resolution) about 75% of the sample are detected above a limit of about 1 mJy at 20 cm. It will of great interest to see whether the correlation between radio continuum and far infrared emission (see e.g. Helou et al., 1985) holds for our sample of high infrared luminous galaxies.

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